Biological Evaluation of Ash Trees at Delaware Water Gap National Recreation Area

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Photos: Photo taken by Chris Hayes

Abstract

In June 2018, Forest Health Protection personnel from the U.S. Forest Service, U.S. Department of Agriculture, Northeastern Area, State and Private Forestry Field Office in Morgantown, WV, and personnel from Delaware Water Gap National Recreation Area (DEWG) visited recreation sites within the park to inspect ash trees. The purpose of the survey was to see if emerald ash borer (EAB), *Agrilus planipennis* Fairmaire, was present and determine the need for management activities to prevent the creation of hazard trees due to EAB-caused tree mortality and to develop strategies to preserve an ash resource into the future. EAB were found colonizing and killing trees at two sites during our survey; both sites were along roads and none were found in any of the developed recreation sites visited. Since EAB have been found killing trees within the park, it is recommended that a comprehensive ash management plan be developed that includes a hazard tree removal plan, biocontrol releases, and the consideration of chemical treatment of a small number of mature ash trees to help preserve ash trees for future seed production.

Purpose and Need

The Forest Health Protection unit of the Forest Service, Northeastern Area, State and Private Forestry Field Office (MFO) in Morgantown, WV, received a request in the spring of 2018 from Larry Hilaire, Wildlife Biologist, and Casey Reese, Regional IPM Coordinator, Northeast Region, USDI National Park Service, to conduct a biological evaluation in regards to EAB that has likely started to colonize and kill ash trees within the park.

DEWG conducted an extensive survey to inventory the ash (*Fraxinus* spp.) in 2006 to determine the location of overstory ash trees within developed recreation sites and determine if targets existed that would cause trees to become hazards if killed by EAB (Perles et al. 2007a, b). Also, a survey of forested areas of the park was conducted to determine the extent of ash within general forested areas of the park (Perles et al. 2007a, b). With this survey information and insight gained from our site visit, recommendations are made here to guide DEWG in the development of a prudent EAB/ash management plan.

Species Evaluation/Background

Emerald ash borer (EAB), *Agrilus planipennis* (Fairmaire), is a wood-boring beetle from Eastern Asia (Poland and McCullough 2006) that is causing severe mortality in North American ash (Tluczek et al.2011), affects all ash species, and often kills both healthy and stressed trees within 3 to 5 years of their becoming infested (Siegert et al. 2006).

Research indicates that emergence of adult beetles occurs when 450 growing degree days have been reached (base 50). This typically occurs at DEWG around the first week of June. Adult beetles are slender, elongate, and bright green. Once emerged, adults feed on ash foliage (Kovacs *et al.* 2010), mate, and females lay eggs individually in bark cracks and crevices. Adult beetles live for about 3-6 weeks and females lay about 60-90 eggs (McCullough and Katovich 2004). Eggs hatch in 7-10 days and larvae then chew through the bark and feed on phloem and outer sapwood for several weeks, creating S-shaped galleries packed with frass (Bauer et al. 2004). Larvae are white to cream colored, flattened, and have 10

segments. EAB overwinter as larvae in shallow chambers in the outer sapwood or bark on thick-barked trees (Bauer et al. 2004), and pupate in late April or May, and adults emerge 1-2 weeks after pupation through D-shaped exit holes (McCullough and Katovich 2004).

The ecological consequences associated with the loss of ash from North American forests are concerning. Studies show that ash trees provide food and habitat for several bird and mammal species (Faanes 1984, Rumble and Gobeille 1998), and that forty-three native arthropod species are at high risk due to their association with ash for breeding or feeding (Gandhi et al. 2010). In addition, ash also contributes to nutrient cycling in hardwood forests (Reiners and Reiners 1970).

EAB was first found in the Detroit, Michigan/Windsor, Ontario area in 2002 and, as of 2018, EAB has been detected in 33 states (Figure 1; 32 states identified in this map plus EAB has now been found in Maine as of June 2018) and the Canadian provinces of Ontario, Quebec, and Manitoba.

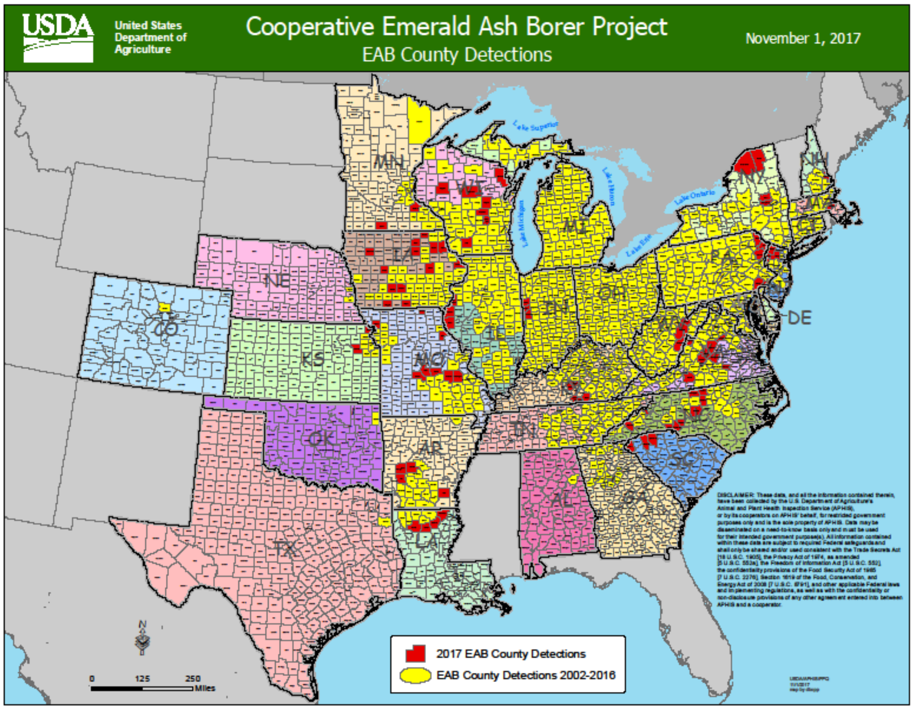

Figure 1. *Current EAB detection map by county for U.S.A., as of November, 2017. States filled in with a particular color (not gray) have a known infestation, yellow counties were infested prior to 2017, and counties in red were first detected in 2017.*

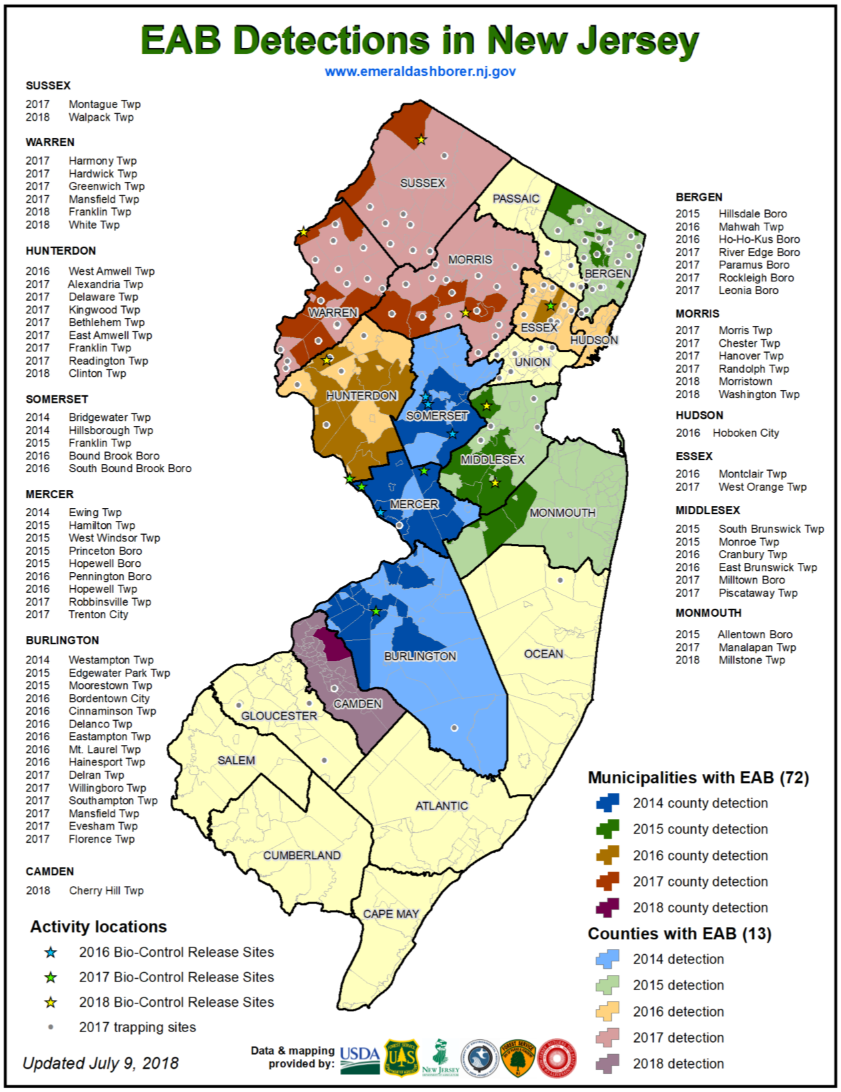

Figure 2. *New Jersey EAB detection map (updated July 9, 2018).*

Project Location/Description

DEWG is located on the boarder of Pennsylvania and New Jersey, encompasses forested areas along the Delaware River, and is a popular recreation area. Within all four counties in which DEWG occurs (Sussex and Warren Counties in NJ, and Monroe and Pine Counties in PA), EAB was found for the first time in 2017. Since positively identifying EAB in purple prism traps, NJ has begun releasing biocontrol agents in Sussex and Warren Counties in summer 2018 (Figure 2).

Ash trees are common and widespread in DEWG, but do not occur as any distinct, “ash dominated forest” types. A vegetation study conducted in 2006 by DEWG (Perles et al. 2007a, b) found that ash occurs in 40 of the 68 vegetation communities described in the park and in nine of the forest types ash trees were relatively abundant (were present in at least 50% of the samples). An analysis of this study showed that ash trees are especially common in the bottomlands and floodplains of the Delaware River and Flat Brook riparian areas, and other mesic habitats. On the Pennsylvania side of the park, ash are most concentrated in the area extending from Hialeah up to Randall Creek (Brodhead Road) and on the New Jersey side of the park, ash trees are more prevalent and widely distributed when compared to the PA side of the park (Figure 3).

EAB infestations within DEWA will very likely lead to a substantial increase in the number of hazardous trees in the park, which is a primary concern. Ash trees occur at varying densities along many of the roads in the park, including Route 209, River Road, Old Mine Road, and Route 615. Ash trees also occur in the vicinity of many visitor use areas like Hialeah, Smithfield Beach, Toms Creek picnic area, Dingmans Campground, boat launches, and many park houses and structures (Table 1).

Project Objectives

We had multiple objectives for this evaluation: 1) to determine whether and where EAB was present in the park at the time of the survey, 2) determine if chemical treatments to protect and maintain high value ash trees and/or biological control releases are appropriate management options, and 3) gauge ash presence along road and developed sites to inform recommendations for hazard tree mitigation strategies.

Project Methods

Our assessment of DEWG was done by combining what we observed in a walk-through of the developed recreation sites at the park during our site visit and information obtained by DEWG through their previous ash surveys. With this information we were able address all three of our objective.

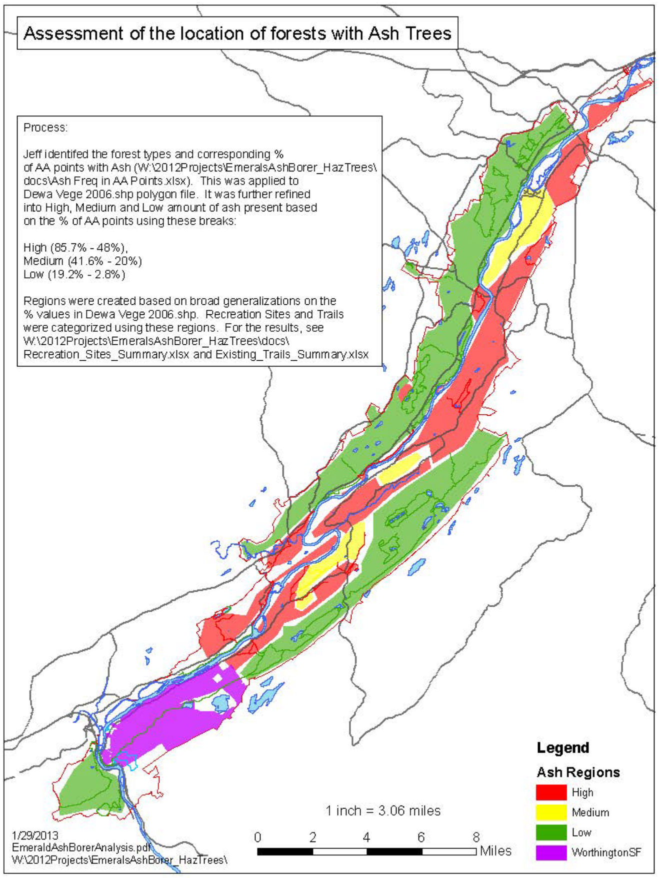

Figure 3. *Ash tree occurrence map created from survey conducted by ~~BEWG~~ DEWG in 2006 (Perles et al. 2007).*

Results

EAB infested trees were found at two locations in the park during our field visit in June, 2018~~, field visit~~: in a single roadside tree and a group of trees, both along Old Mine Road on the New Jersey side of the park. We did not confirm the presence of EAB in any of the ash trees inspected at the 17 recreation sites that we inspected (Table 1). Of these sites, a number of recreation sites have a large number of ash trees, most notably Dingman's Campground, Valley View Group Camp, and Hialeah Picnic Area.

DEWG has extensive ash resources that they have inventoried. Their assessment of developed recreation sites found 429 ash trees that will likely become hazard trees (Table 1). In addition, the NJ side of the

park has ash commonly found in much of the forested areas (Figure 3), and the extensive road and trail systems within these forests will present challenges from a hazard tree perspective.

Table 1. *Tallies and the cumulative diameter of ash trees found in developed recreation sites in Delaware Water Gap NRA in a 2006 survey. Potential hazard trees were those that had a nearby target; targets included roads, parking lots, picnic tables, campsites, structures, and sidewalks.*

SITE	1-4" DBH Ash	> 4" DBH Ash	Total # Ash	Cumula-tive DBH (in)	Potent. Hazard Trees	Total Targets
Pennsylvania						
Milford Beach & Access	0	0	0	0	0	0
Dingmans Access	22	35	57	362	34	46
Dingmans Campground	7	124	131	1865	100	200
Eshback Access	0	0	0	0	0	0
Toms Creek Picnic Area	4	3	7	41	1	1
Valley View Group Camp	32	76	108	801	46	105
Bushkill Access	37	19	56	208	10	13
Smithfield Beach and Access	5	83	88	1293	74	77
Hialeah Picnic Area	19	91	110	1399	68	156
New Jersey						
Thunder Mountain	1	4	5	82	3	7
Walpack Center	0	4	4	34	0	0
Millbrook Village	0	45	45	686	42	82
Watergate	1	11	12	109	10	12
Van Campens Glen Rec. Area	9	7	16	85	3	4
Poxno Beach	1	6	7	82	6	11
Turtle Beach	43	27	70	320	22	32
Kittatinnty Point	10	10	20	173	10	16
TOTAL:	**191**	**545**	**736**	**7540**	**429**	**762**

Figure 4. *Karen Felton and Larry Hilaire inspecting EAB-infested ash tree at DEWG, June 2018.*

Discussion

Because of the large number of ash trees located in recreation sites and along roads and trails throughout the park, it is important that DEWG develop a hazard tree plan and begin to implement ash removal work as soon as is feasible. The primary reason to begin tree removals prior to the impending large-scale ash mortality event is that delaying the implementation of this work will leave the park with an excessive number of dead ash trees needing removal and that will likely be more than the park can deal with in a short period of time, thus leaving many hazard trees with the potential to injure visitors.

In the initial stage of EAB infestation, ash damage can be hard to detect as populations are low and tree damage begins in the tops of ash trees where it is hard to detect. EAB populations start to increase in the first few years of introduction and from four to seven years after a county has been declared to have EAB, high ash mortality rates will occur (Morin et al. 2015). For individual trees, EAB kills both healthy and stressed trees within 3 to 5 years of a tree becoming infested (Siegert at al. 2006). Typically, in any one area, the ash mortality becomes very noticeable after five years.

When ash trees die they rapidly become brittle and are prone to breakage. This makes dead ash hazardous to remove. The cost of tree removal can vary widely depending on the location of the tree and, in some cases, treating with pesticides for the remaining life of a tree may not cost any more than the cost of the up-front removal, especially if the removal is costly or too dangerous to the remover (Liu and

Miller 2014). Your ash tree removal plan should anticipate tree removal work in many years to stagger the cost of tree removal over time.

In addition to managing hazard trees, chemical and biological control are the two main tools employed in EAB management. Although neither of these treatment options is a panacea for this problem, they both should be consider. Chemical control is only practical for a relatively small number of tree as it is costly, time consuming, and trees will require additional treatments in perpetuity or until biocontrol agents are effective at limiting EAB population growth. At this point in time, researchers are working to develop long-term strategies that utilize tree breeding (breeding ash for EAB resistance) and biocontrol (introduction of parasitoids that utilize EAB eggs or larvae for reproduction) that will create conditions that limit EAB reproduction and allow for ash seedlings to grow into mature, overstory trees.

Systemic insecticides have become the standard pesticide treatment option for protecting trees from wood-boring beetles. They are the preferred due to their effectiveness, length of efficacy, and low relative impact on non-target organisms. A number of the active ingredients in products registered for this use are neonicotinoids and, due to concerns of negative impacts on native bees, are currently under review by the Environmental Protection Agency.

The basic guidelines used to determine when to treat for EAB is when areas are within a quarantined county or within 10-15 miles of a known EAB infestation (Herms et al. 2014). It can be difficult to find a balance between tree removal and treatment. In an ideal world, we would treat all ash trees; however treatment is labor intensive and it may not be fiscally possible to keep retreating all trees every 1-3 years, depending on the pesticide selection and local EAB densities. Some chose to chemically treat trees that are considered high value and their loss would drastically change the character of the site. You may, however, wish to chemically protect a group of trees for the goal of conserving a local ash seed source. If so, then the following approach may be implemented: select at least 10 good specimen trees (e.g. dominate, healthy, good seed producers) at a sex ratio of at least 5:1 (females:males) and treat every 1-3 years, depending on the pesticide selection and local EAB densities (Liu and Miller 2014). This treatment is usually done in a wooded area away from developed sites.

An accepted ash tree treatment requirement is that crown dieback is 30% or less, while also taking into consideration of any defects, such as decay or poor form; trees with both wood decay and EAB damage should not be chemically treated. Sometimes 31-60 % crown dieback may be used if the tree has been designated as treatable by other characterizations (e.g. very high value, location), knowing the tree will never replace the lost crown. Any tree with great than 50% dieback cannot be expected to survive even after treatment (Herms et al. 2014)~~, however~~.

In some areas of EAB infestations, a small number of ash trees have been observed to be surviving EAB infestation and are referred to as lingering ash. These trees may have some natural resistance to EAB and could provide the genetic material for the next generation of ash trees and, at this time, collections of seeds from these trees are being made to test for EAB resistance.

Management Options

No Action Option:

In this option, emerald ash borer is allowed to infest ash trees within the park and would result in almost all (99%) ash trees greater than 1" dbh being attacked and killed as a result of EAB. This would result in the loss of high value ash and woodland ash trees, which would increase hazard trees in public areas and cause a reduction in overstory canopy. No overstory ash will remain in any of the developed recreation sites. In wooded areas, ash seedlings will remain but with no management action the probability of any of these seedlings growing to become overstory trees in very low. Although no actions are planned in this option, tree removals will likely occur as hazards to visitors pushes the park to take action.

Chemical Insecticide Option

There are a number of chemical control options for EAB that include systemic basal trunk sprays, soil-applied systemic insecticides, trunk-injected systemic insecticides, and protective cover sprays (Herms et al. 2014). The selection of an insecticide option is determined by cost, length of efficacy, non-target effects, pollinator concerns, and speed and ease of application.

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Insecticide treatments being used for EAB have been developed with a goal of limiting impacts on non-target organisms and the environment in general, but considering how to limit these impacts helps determine the appropriate treatment selection. Some of the chemicals used in pesticide treatments are highly toxic to aquatic vertebrates and application should be avoided when soils are water saturated or when drift may settle on bodies of water. Injected systemic insecticides are often chosen because there is no drift with this treatment. Soil injections and drenching do not have drift issues either, but care should be taken to avoid these treatments when soils are water saturated. Pesticide labels include information on toxicity to non-target organisms and precautions that need to be taken, so always consult and follow pesticide labels.

Most chemical treatments are systemic, meaning the insecticide is taken up by and incorporated into all parts of the tree. When any insect eats a leaf of burrows through the bark they ingest the poison, typically a neurotoxin, and are killed. Systemic insecticides, because they are incorporated into the tree, do not break down rapidly and can be effective for up to three years.

Most pesticides listed for use on EAB are restricted-use pesticides, meaning they can only be applied by a certified pesticide applicator, but there are a few products that can be used for EAB that are not restricted use (Table 2). Although we do not endorse one particular product or treatment, we would like to discuss some of the benefits and drawbacks of particular treatments.

Soil Applications

Drenching and soil injections are convenient treatment methods and products are available that require a certified applicators license and some that do not require an applicator license. Application requires little to no specialized equipment to apply. Products for drenching and soil injections typically have the active ingredient imidacloprid or dinotefuran. Soil injections of imidacloprid should be made 2-4 inches below the soil surface for good root uptake, as it can bind to organic materials in the soil. For large trees and

when EAB population levels are high it is suggested that chemicals should be applied at the highest application rate, but care should be taken not to exceed the per acre limitations stated on the label.

Protective Cover Sprays

Protective cover spray is another method for protecting trees from EAB. Since EAB attack smaller branches, the trunk and the bark of all branches must be sprayed for EAB treatments. In larger trees this may be difficult to achieve. This treatment requires specialized pesticide spray equipment and there is considerable drift with chemicals potentially landing on unintended targets. Another drawback of this treatment is that it does not kill EAB that is already within the tree, as it is designed to kill wood boring insects as they attack the tree. Chemicals used for protective cover sprays include permethrin, bifenthrin, cyfluthrin, and carbaryl.

Trunk Injections

Trunk injections require specialized equipment and considerable expertise to apply. However, there is no drift associated with this treatment nor is there the water runoff potential of soil injections and drenching. Uptake of chemicals is faster in truck injections than in soil applications (Herms et al. 2014). Trunk injection involves drilling holes through the bark and sapwood at the base of the tree and injecting pesticides directly into the tree. Formulations of azadirachtin, emamectin benzoate, and imidacloprid are used for truck injections, and trunk injection of emamectin benzoate in mid-May or early June provides consistent control of EAB, and can provided multiple years of protection (up to 3 years)(Smitley et al. 2010). A natural product, azadirachtin, is also available formulated as TreeAzin™, which is injected into the trunk of the tree as a systemic. This product is a tetranortriterpenoid compound extracted from the seed kernels of neem (*Azadirachta indica*) (Fares et al. 1980).

Biological Control Option

Currently, four parasitoid wasps, including three gregarious larval endoparasitoid species (*Spathius agrili*, *Spathius galinae*, and *Tetrastichus planipennisi*) and a solitary parthenogenic egg parasitoid (*Oobius agrili*) are available for release against EAB through the USDA APHIS EAB Biological Control Program. Guidelines on site selection and methods for release and recovery have been published (USDA-APHIS/ARS/FS 2012) for those interested in participation in the program. Biocontrol releases are typically done once EAB populations have built up so the parasitoids have sufficient numbers of EAB eggs and larvae on which to lay their eggs. The release and establishment of EAB natural enemies is not likely to provide any short-term control of EAB but may provide significant population pressure sometime after outbreak populations have collapsed after the loss of most overstory ash. Research into the success and establishment of these biocontrol agents is ongoing (e.g., see Jennings et al. 2016). Duan et al. found *Tetrastichus planipennisi* has successfully established self-sustaining populations in Michigan and is suppressing EAB populations in ash-dominated forests. Researchers are hopeful that these parasitoids will play a vital role in the long-term preservation of ash as a forest tree.

Table 2. *Insecticides used to protect ash trees from emerald ash borer attack. This is not an exhaustive list. Pesticide registration varies by state, so always consult your state prior to use to confirm that a specific production is registered for use in that state. Table taken from Herms et al. 2014*

Insecticide Formulation	Active Ingredient	Application Method	Recommended Timing
Products Intended for Sale to Professional Applicators			
Merit® (75WP, 75WSP, 2F)	Imidacloprid	Soil injection or drench	Early to mid-spring or mid-fall
Safari ™ (20 SG)	Dinotefuran	Soil injection or drench	Mid- to late spring
Transect ™ (70WSP)	Dinotefuran	Soil injection or drench	Mid- to late spring
Xylam® Liquid Systemic Insecticide	Dinotefuran	Soil injection or drench	Mid- to late spring
Xytect™ (2F, 75WSP)	Imidacloprid	Soil injection or drench	Early to mid-spring or mid-fall
Azasol™	Azadirachtin	Trunk injection	Mid- to late spring after trees have leafed out
Imicide®	Imidacloprid	Trunk injection	Mid- to late spring after trees have leafed out
TREE-äge™	Emamectin benzoate	Trunk injection	Mid- to late spring after trees have leafed out
TreeAzin®	Azadirachtin	Trunk injection	Mid- to late spring after trees have leafed out
Safari™ (20 SG)	Dinotefuran	Systemic bark spray	Mid- to late spring after trees have leafed out
Transect (70 WSP)	Dinotefuran	Systemic bark spray	Mid- to late spring after trees have leafed out
Zylam® Liquid Systemic Insecticide	Dinotefuran	Systemic bark spray	Mid- to late spring after trees have leafed out
Astro®	Permethrin	Preventive trunk, branch, and foliage cover sprays	Two applications at 4-week intervals; first spray should occur at 450-550 degree days (50°F, Jan.1); coincides with black locust blooming
Onyx™	Bifenthrin		
Tempo®	Cyfluthrin		
Sevin® SL	Carbaryl		
Products Intended for Sale to Homeowners			
Bayer Advanced™ Tree & Shrub Insect Control	Imidacloprid	Soil drench	Early to mid-spring
Optrol ™	Imidacloprid	Soil drench	Early to mid-spring
Ortho Tree and Shrub Insect Control Ready to Use Granules®	Dinotefuran	Granules	Mid- to late spring

Management Alternatives

Below we recommend a number of management alternatives. It is important to remember protecting ash trees from EAB-cause mortality is difficult and ash management should be approached as a long-term effort.

Alternatives

Alternative 1.	Implement hazard tree management plan.
Alternative 2.	Implement hazard tree management plan and, once EAB becomes established and conditions are appropriate, conduct biocontrol releases.
Alternative 3.	Implement hazard tree management plan, conduct biocontrol releases, and select a group of mature ash trees to treat with pesticides to preserve an ash seed source.

Recommendations

We recommend that the DEWG Staff develop a comprehensive ash/forest management plan that is implemented as soon as possible and consider treating some select, high value trees with chemical treatments and conduct biocontrol releases. In addition, we recommend that DEWG begin a public awareness campaign about EAB and continue to annually monitor tree health conditions and survey for signs and symptoms of EAB infestations. In addition to visual surveys, attractant-baited traps can be used to survey for low levels infestations of EAB. The MFO can assist DEWG on preparing a monitoring plan for using the traps (e.g. quantity, trap type, trap locations, etc.), and can provide education materials.

We recommend Alternative 2 based on the following considerations:

1. Ash trees within developed recreation sites, in our opinion, if lost to EAB would not heavily impact the character of these sites.
2. We also recommend releasing EAB parasitoids in EAB infested areas, if this does not conflict with the park's management plan. The establishment of these natural enemies is experimental, but may offer the opportunity for long-term control and allow for the reestablishment of overstory ash trees in the future.
3. DEWG may choose to chemically treat some trees, but we feel that the long-term viability of ash as a forest tree in this area will depend on successful biocontrol and development of EAB-resistant trees through breeding efforts and chemical treatment of trees at DEWG may not be necessary.

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